Northern Power Systems

Distributed Generation Applications

DOE Roadshow - Burlington, VT

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Jim McNamara

NORTHERN POWER SYSTEMS

Reliable power. Proven worldwide.

Company Overview

Northern Power Systems designs, builds and installs high-reliability leading edge electric power solutions:

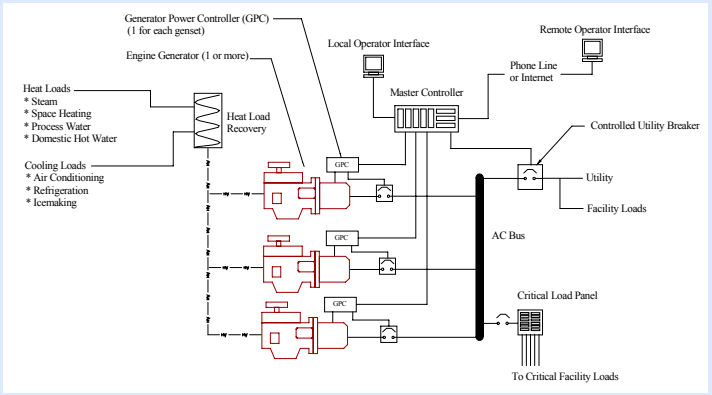
- Turnkey systems integrator
- Over a quarter century of Distributed Generation experience
- 800 projects installed on all 7 continents
- 90 employees (over 50% with engineering degrees)
  - Vermont base with San Francisco field office
- Broad client base
  - AT&T, Chevron, Bechtel, PG&E, Siemens
  - DOE, National Science Foundation, NASA
  - Conn College, Middlebury College, Yale

The Northern Approach

- Offer turnkey, value engineered solutions:
  - Systems design and engineering
  - Construction and installation
  - Commissioning and training
  - Maintenance, monitoring, and control
- Open technology stance
- Focus on optimizing performance and maximizing value for clients
- Combine best-of-breed generation technology with advanced system controls and software
- History of solving difficult engineering problems

Northern Technology Competencies

- Power Generation:
  - Reciprocating Engines
  - Microturbines
  - Fuel Cells
  - Wind
  - Solar
- Heat Recovery & Thermal Energy Management
- Energy Storage
- Control Systems
- Data Acquisition and Monitoring
- Environmental Enclosures



Northern's Market Focus

Research & Development

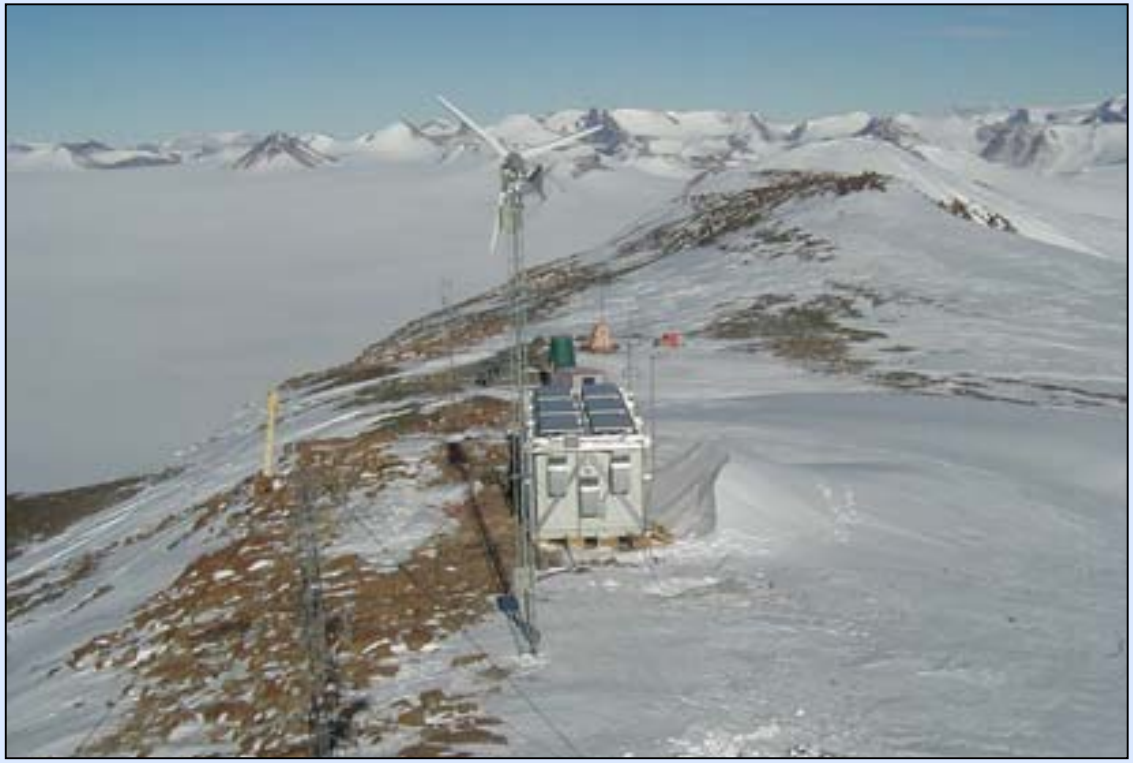
Remote Generation

Green Generation

On-Site Generation

Sample Projects

– High reliability in world's harshest environment



- 3,000 Watt solar array
- 3,000 Watt wind turbine
- Diesel genset
- Environmental package for environment at -70°F
- **Northern**™ SC-1000 system controller
- **RemoteView**™ monitoring software

Mt. Newell, Antarctica (6,700' - Helicopter Access Only)
Communications Relay Site for Nuclear Test Ban Monitoring Stations

Sample Projects

- Large scale project management

Caspian Sea Oil Pipeline, Russia and Kazakhstan

GridTie™ power shelters for valve actuation and SCADA

113 locations:

- UPS for valve actuation and telecommunications
- Cathodic protection
- 380 VAC and 48/24 VDC switchgear and distribution
- Utility and genset inputs
- Designed for extreme temperatures, salt exposure, seismic events, and security
- Remote monitoring and control
- Five specialized shelter types

Sample Projects

- Complex hybrid system engineering

- 225 kW Vestas Wind Turbine
- 2 x 150 kW Volvo Diesel Gensets
- No Battery Bank Required
- Digital Engine Controls
- NPS Components
  - System Controllers/RemoteView
  - Synchronous Condenser
  - Heating and Thermal Plant
  - Integrated Control Shelter
  - Dump Load Regulator

St. Paul Island, Alaska

Wind/diesel hybrid cogeneration system providing electricity and space heat to an industrial/airport facility

Sample Projects

– Turnkey delivery of power and distribution systems

- 314 kW diesel generator plant (Two 120 kW, one 74 kW)
- PLC for intelligent dispatch
- Digital Engine Controls

- Upgraded distribution to 4,160V,with transformer nodes for 120/240V
- Custom noise abatement package

Monhegan Island, Maine
Public Power Utility

Sample Projects

– Research & Development in advanced DG solutions

Capstone Microturbine being tested by Northern Power Systems

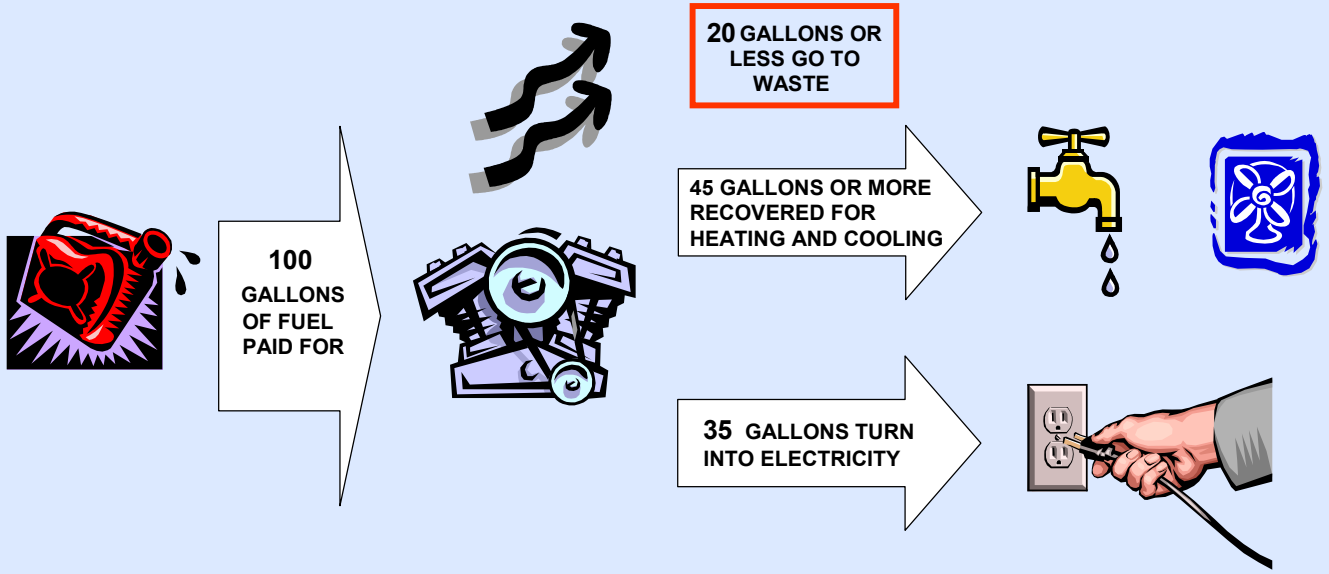
- Honored with R&D 100 Award for technological excellence in 2000
- R&D contracts with DOE, NASA, NSF, NREL, Sandia
- Evaluation of emerging DG technologies including electrolysers, fuel cells, microturbines, flywheels
- Product development efforts:
  - System controls
  - Energy management software
  - Advanced power electronics
  - Advanced DG networks

Distributed Generation

- Cogen
- DG
- Combined Heat and Power
- CHP
- Critical Load Support
- Peak Shaving . . . .

Combined Heat and Power

- CHP systems generate electricity and thermal energy in a single cost and energy efficient integrated system
- Engine, turbine or fuel cell
- Recovered heat used to create hot water or steam to run heating or cooling systems or other industrial processes



Customer Benefits from CHP

- Lower energy costs
- Fast return on investment, unlike a backup generator
- Manage volatility of energy costs
  - Lock in energy cost with long term natural gas contract
- Increase security of energy supply
  - Reduce risk of planned or unplanned outages
  - Protect critical process loads from utility disturbances
- Improve energy efficiency
  - Capture waste heat from engine to meet building thermal demand
  - Reduce greenhouse gas emissions
- Create positive PR from reliable, clean energy supply

Uses for Recovered Heat

Heat Loads

- Steam
- Space Heating
- Process Hot Water
- Domestic Hot Water

Cooling Loads

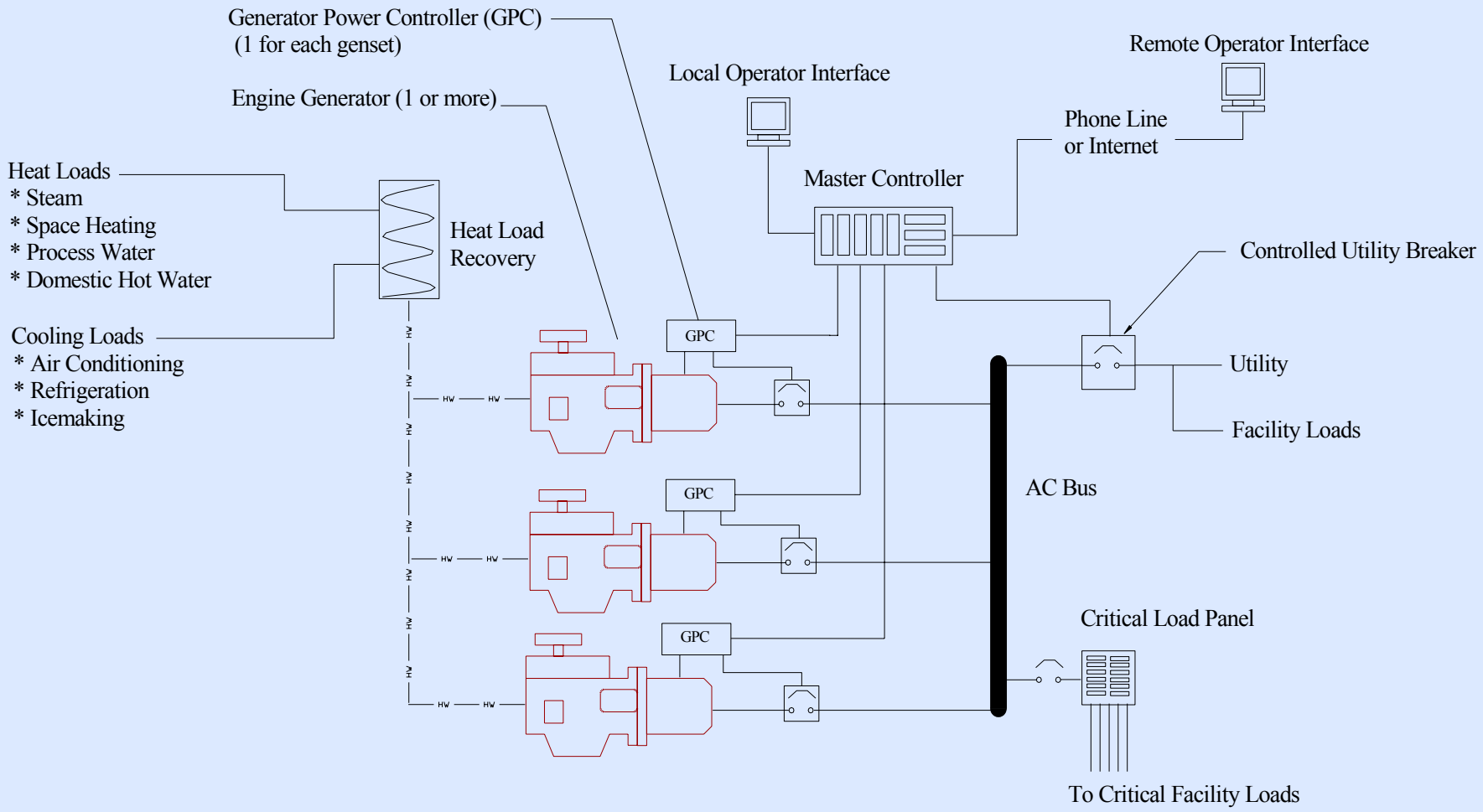
- Air Conditioning
- Refrigerating
- Ice making
- Dehumidification

CO_2 Savings from CHP Systems

Technology	Efficiency without CHP	Efficiency with CHP	CO_2 Emissions (lb/MWh)	CO_2 Savings vs. Grid (lb/MWh)
Fuel Cells	35 - 45%	80 - 85%	534 - 568	434 - 468
Microturbine	20 - 25%	80 - 85%	534 - 568	434 - 468
Reciprocating Generators	30 - 35%	75 - 80%	568 - 605	397 - 434

CO_2 savings based on grid emissions of 1002 lb CO_2/MWh, assuming use of recovered heat displacing grid power.

Typical On-Site System Design with CHP

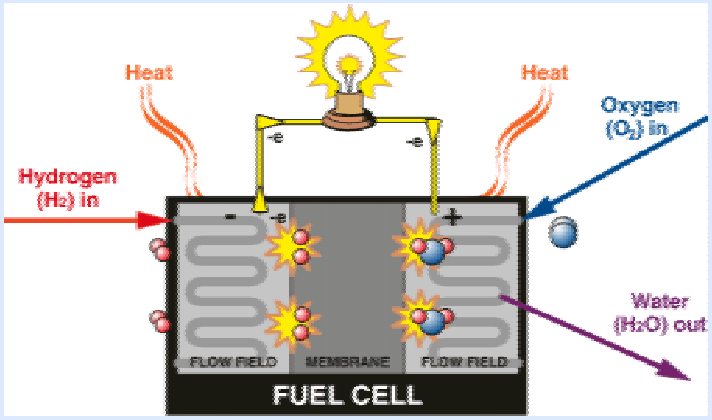


On-Site Fossil Fuel Technologies

MicroTurbine

Reciprocating Gensets

Fuel Cells



Natural Gas Reciprocating Engines

- Conventional internal combustion engine
- Spark Ignition or Dual Fuel
- System Sizes: 50kW – 10 MW
- Electrical Efficiency: 25% - 42%
- Mature Products
- Multiple Sources

Benefits of Natural Gas Engines

- Low capital cost
- Easy start-up
- Ability to handle rapid changes in demand
- Proven reliability when properly maintained
- Proven maintenance costs
- Easy to capture waste heat
- CO_2 Emissions: 1300 – 1500 lb/MWh (w/out heat recovery)

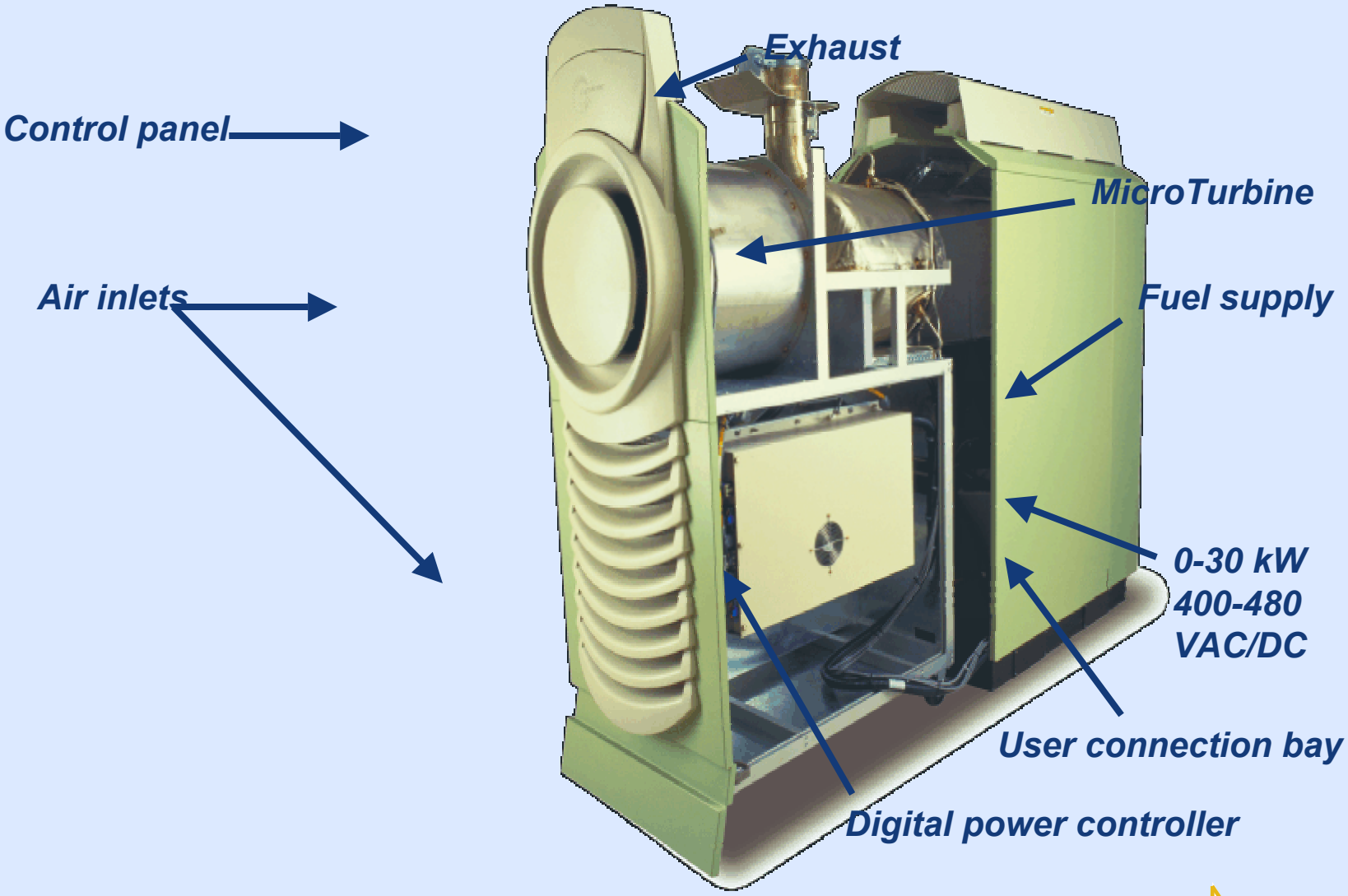
Microturbines

- Small-scale version of a gas turbine, analogous to a jet engine
- 6 Different Manufacturers
- Electrical Efficiency: 20% - 28%
- Up to 85% Efficiency with heat recovery
- Diverse Fuels Applicable
- System Size Range: 30kW – 200kW

Benefits of Microturbines

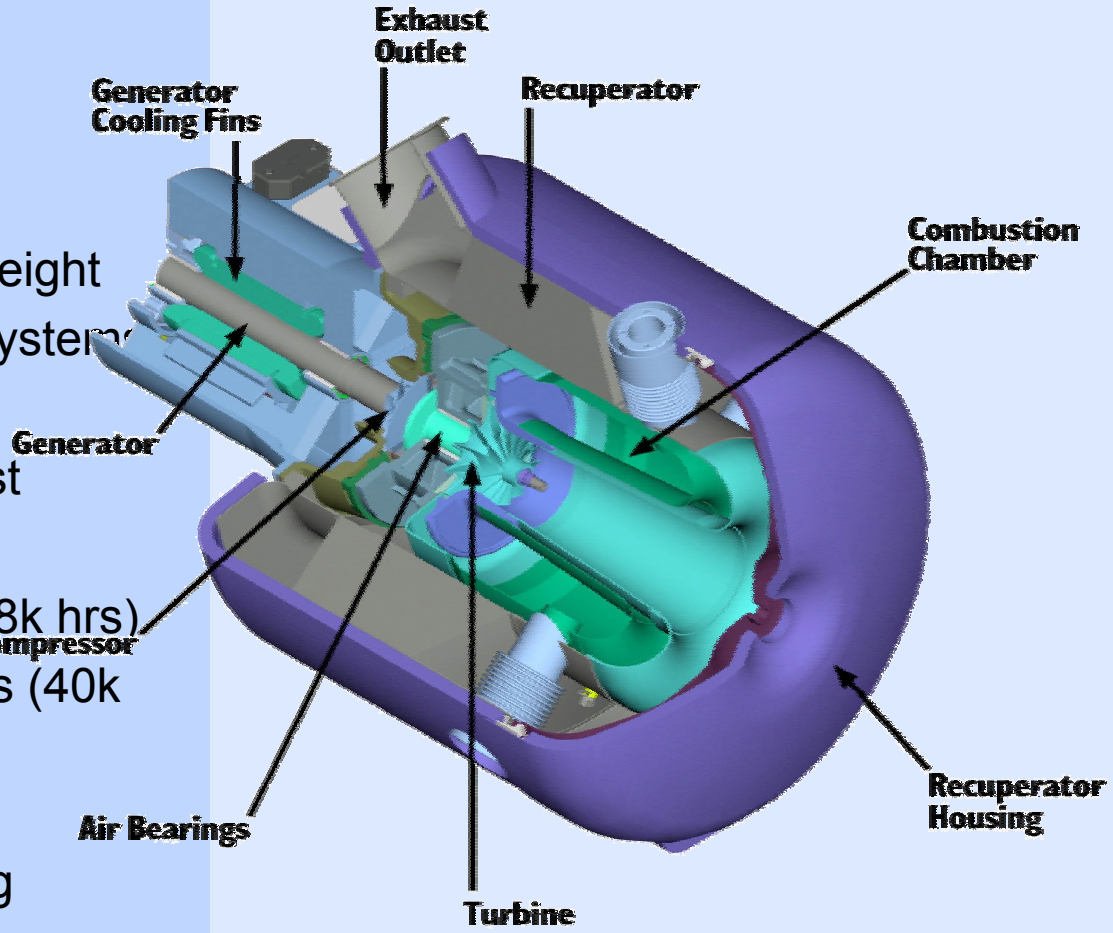
- Compact size
- Modular
- Very quiet
- Low pollution emissions
- Small footprint
- Utility Intertie or Stand Alone

Inside the Capstone MicroTurbine



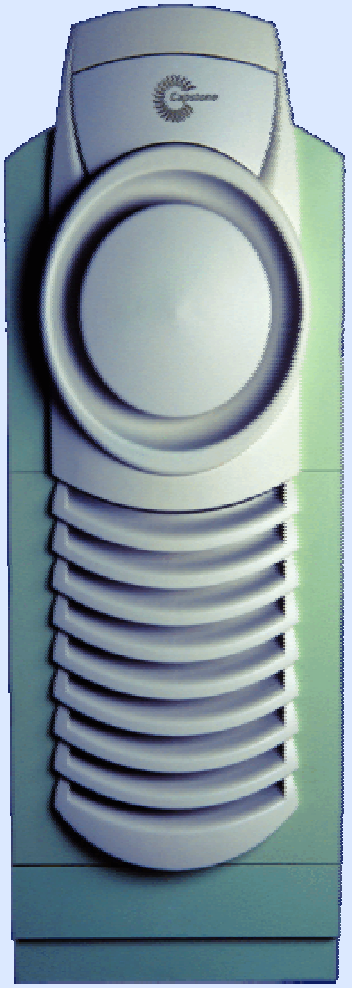
Deep Inside a MicroTurbine

- One moving part
- No liquid coolants
- No liquid lubricants
- NO_X <9 ppm
- Compact and lightweight
- No gearbox or subsyste
- 98+% availability
- Comparably low cost
- Low maintenance
  - minor: once/yr (8k hrs)
  - major: once/5yrs (40k hrs)
- Clean, dry exhaust
  - air/water heating
  - absorption chilling
  - process drying



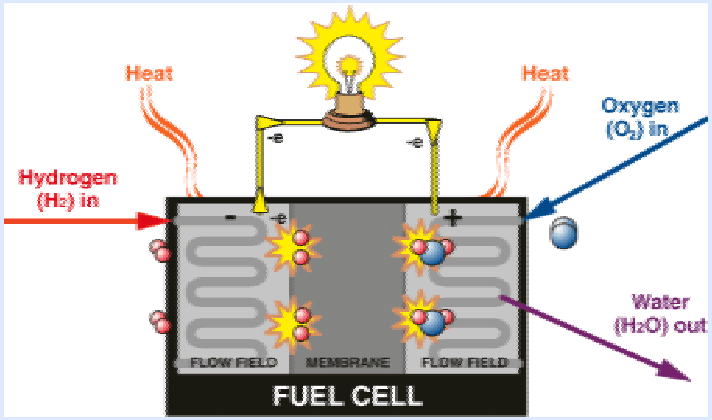
Fuel Capabilities

- Natural Gas
- Up to 7% sour (H_2S) gas
- Propane
- Diesel
- Kerosene
- CNG/LNG
- Methane
- Low-grade landfill/digester gases
  - As low as 350 Btu



Emerging Technologies: Fuel Cells

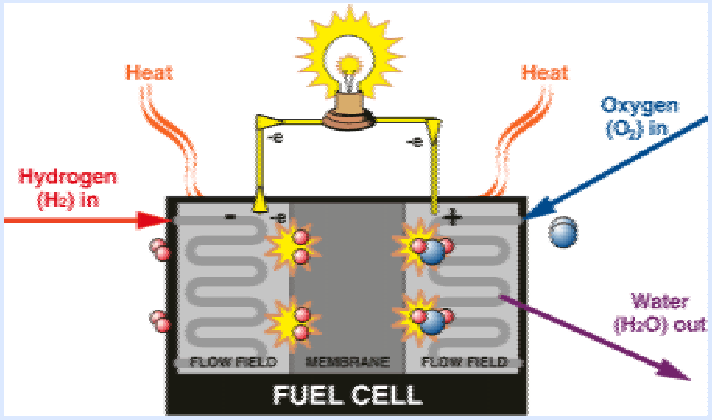
- Electrical generation from fuels with no moving parts
- Fuels - hydrogen directly or from fossil fuels via reformers
  - Fossil fuels directly
- Types of fuel cells:
  - Alkaline Fuel (ACF)
  - Phosphoric Acid (PAFC)
  - Molten Carbonate (MCFC)
  - Proton Exchange Membranes (PEMFC)
  - Solid Oxide
- Size range: 0.5kW – 250kW



In many respects this is a new technology. At present only MCFCs and PAFCs are commercially available. These systems use natural gas as their primary fuel.

Fuel Cells Benefits

- High Electrical Efficiency 50 to 60%
- Extremely long life, no moving parts
- Very low maintenance
- Very high reliability
- Very low emissions



What is a Fuel Cell?

- Electrochemical engine that coverts hydrogen and oxygen into water, heat, and electricity

$H_2 \rightarrow 2\ H^+ + 2\ e^-$

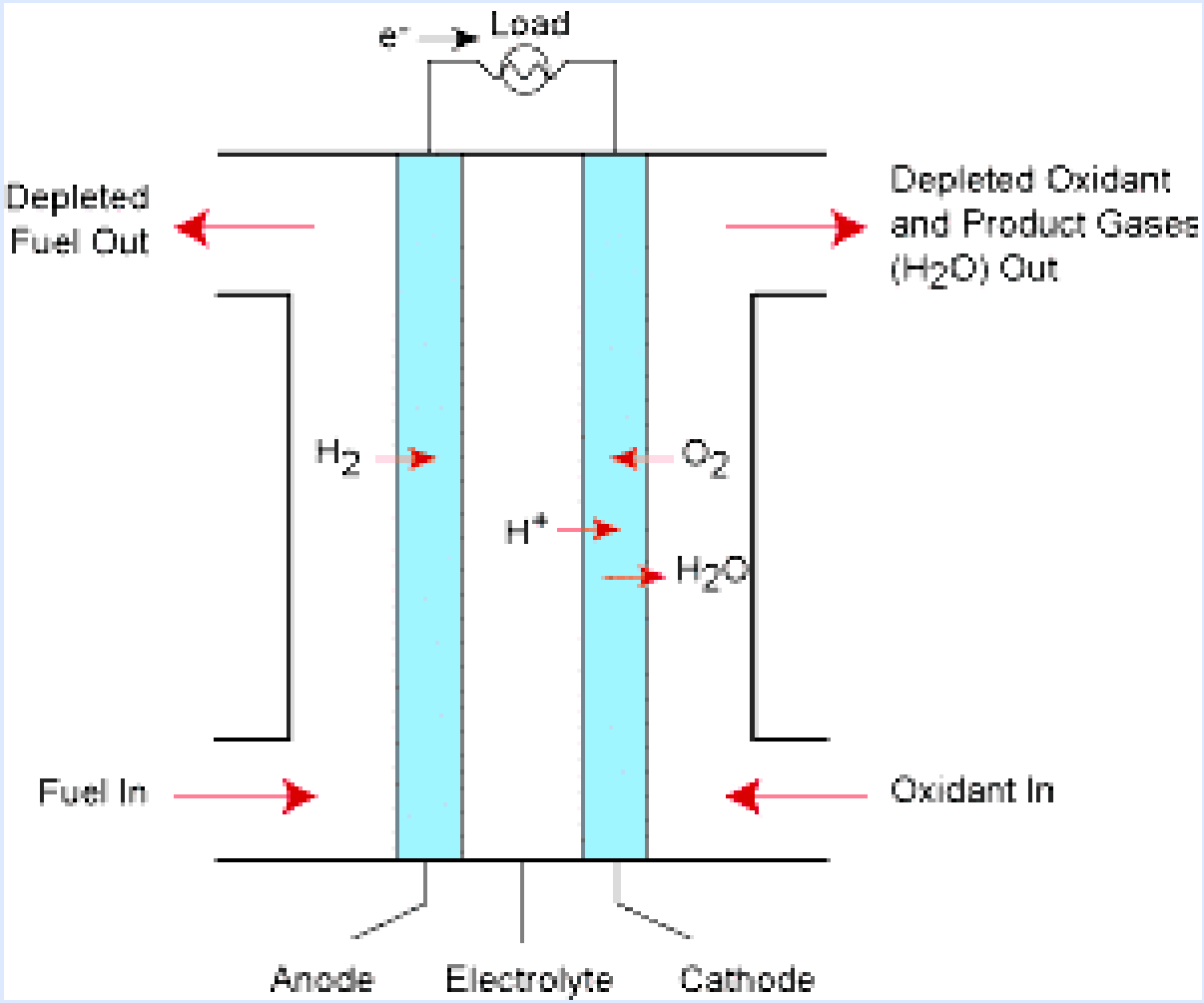
$\frac{1}{2}\ O2 \rightarrow O^-$

$2\ H^+ + 2\ e^- + O^- \rightarrow H2O$

$H2 + O2 \rightarrow H20 + Heat + Electric\ Power$

- Similar to a battery, fuel cells convert chemical energy to electrical energy using no moving parts. Unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.

PEM Fuel Cell



Customers' Energy Problem

- Escalating electric rates in many states
  - Rates exceed 10 cents per kWh in much of California/Hawaii/North East/Mid Atlantic
- Declining reliability and quality of utility power combined with higher demands of digital age.
  - High risk of planned and unplanned outages
  - Increasingly sensitive to voltage sags and other disturbances
  - High cost of lost productivity and product/data

Ideal Facility Profile

- Customer Profile:
  - Multi-shift or continuous operation
  - High cost of outages
  - Recognizes PR value of reliable, clean, energy supply
- Electrical load profile:
  - Peak loads greater than 300 kW
  - High, consistent base load
  - Load sensitive to utility disturbances
- Thermal load profile:
  - High demand for process heat or steam, cooling
  - Thermal load coincides with electric load
  - Low pressure steam or hot water system
- Regional Spark Spread:
  - Expensive Electric Power
  - Cheap Fuel

Northern's Solution

- Turnkey design, engineering, and installation of On-site generation systems
- Typical On-Site Combined Heat and Power (CHP) system includes:
  - Natural gas fired reciprocating engine generator, combustion turbine or microturbine
  - Heat recovery applied to thermal load
  - Switchgear and controls to run parallel with grid
  - Critical load support for key customer processes
  - Remote monitoring and alarming
  - Long term maintenance contract
  - All local, state, air quality, and utility permits

GMCR Example

- Coffee Roasting an Uninterruptible Process
- Equipment Sensitivity
  - Old PLC with no internal battery
  - Mechanical relays and interlocks
  - Motors for fans, tumblers and conveyors
- 208 and 240 VAC distribution



GMCR Solution

- On-Line Generation
  - •Water jacket heat recovery
  - • Exhaust heat recovery
- Fast Utility Disconnect Switch
  - •Less than 5 cycles of deviation
- Small UPS for PLC
- NPS Master Controller
  - • System supervision
  - • Remote access option
  - • Data acquisition and processing

GMCR Results

- 6 Nines reliability (99.9999%)
  - Average utility feed is 3 nines (99.9%)
  - 5 utility incidents/month average
- Tuned to achieve performance Goals
  - Sensitivity vs. Efficiency vs. Robustness
- Provided
  - Back-Up Power
  - CHP Benefits
  - Peaking Plant Economics
  - Enhanced Reliability for Critical Loads

California Bottling Plant Example

Customer:

- Large West Coast Beverage Bottler
- 2 MW peak load, large steam load
- Two-three shifts, 7 days a week.

Customer Problem:

- Escalating Energy Costs
  - 43% electric price increase in 2001
  - 14.5 cent/kWh average electric cost
- Declining Reliability of Utility Power
  - 24 power failures in the past two years
  - $115,000 annual cost of downtime

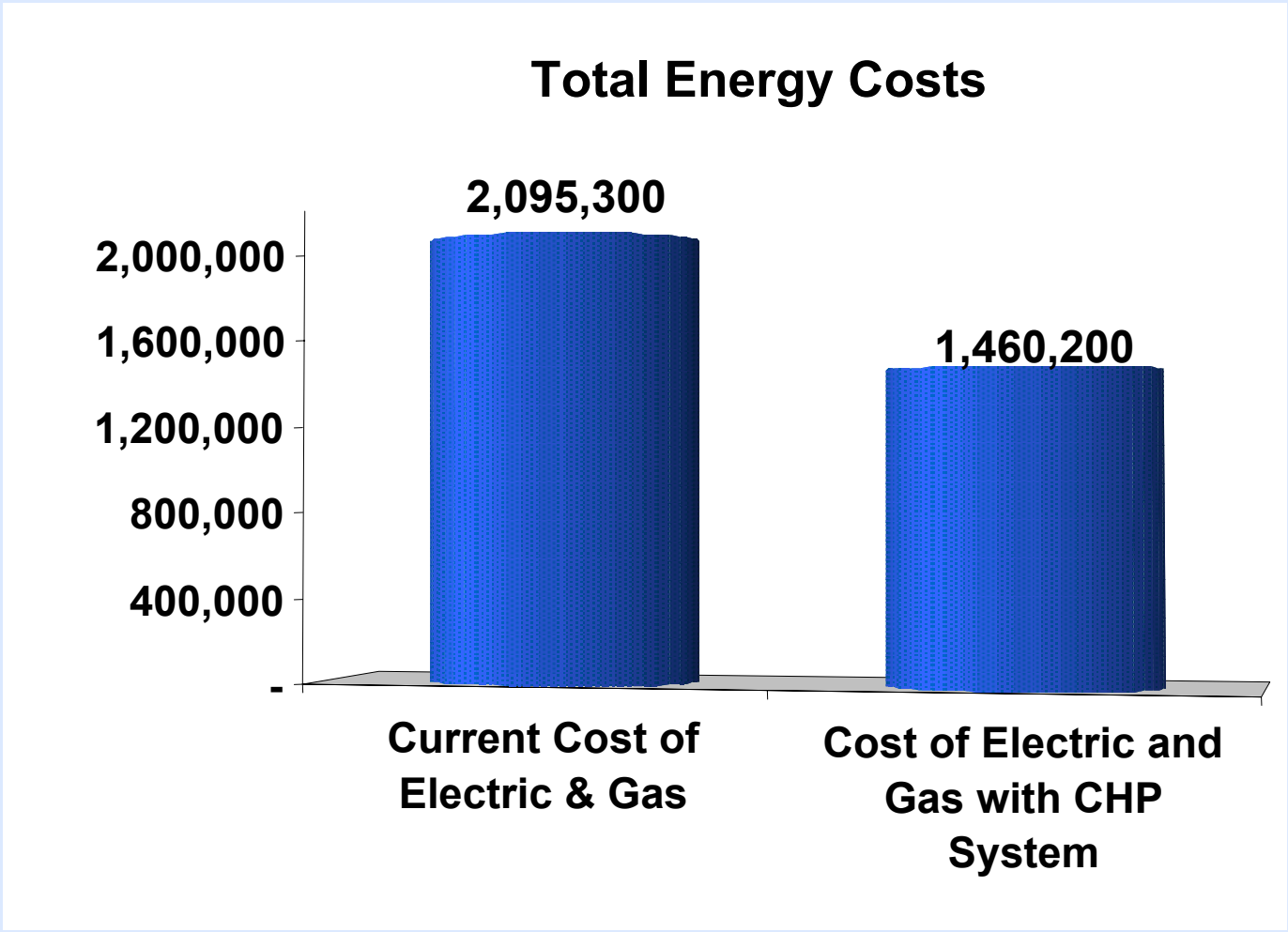
California Bottling Plant Example

Northern Solution:

One Megawatt Combined Heat & Power System with Critical Load Support

- Generates 62% of facility electricity
- Offsets 19% of natural gas used to produce hot water
- Provides uninterrupted power to production lines
- Annual energy savings = $635,000
- 1.6 year payback after 30% California incentive

California Bottling Plant Example



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